REMARKS

Claims 16-30 remain in the application.

The specification is amended to update the status of several related patent applications that have issued as U.S. patents.

The present Preliminary Amendment is being filed with a Request for Continued Examination and is in response to the Office Action dated September 2, 2004, finally rejecting the claims in the prior application. The present Amendment is directed only to the remarks in that rejection. All references to rejections in other applications in prior responses are regretted and are omitted here. Further, an Information Disclosure Statement, identical to the one submitted in the prior application, is submitted herewith, but with the appropriate serial number.

At the outset, Applicants acknowledge that there has been much confusion in the serial numbers of the related applications. The primary related application, for example, has been referred to as serial number 09/280,048, when, in fact, it is 09/282,048 (now U.S. Patent 6,459,095). Applicants have endeavored to amend the specification to correct these errors.

For the convenience of the Examiner, the erroneous serial number, the correct serial number, and the patent number, if issued, are provided below:

Erroneous Serial Number	Correct Serial Number	Issued Patent
09/280,045	09/282,045	----
09/280,049	09/282,049	6,256,767
09/280,048	09/282,048	6,459,095

It is noted for the record that serial numbers 09/280,225 and 09/280,189, cited in the first paragraph on page 1 of the specification are correct.

Claims 16-30 are rejected under 35 USC 112, first paragraph, as containing subject matter which was not described in the specification in such a way as to enable one skilled in the art to which it pertains, or with which it is most nearly connected, to make and/or use the invention. The objections raised by the Examiner are dealt with serially.

(A) The Examiner argues that Claim 16 refers to two crossed wires having a functional group attached to form a junction, but there is no description of how the wires are formed, how

the coating is performed, or how the wires are brought and held in proximity. The Examiner contends that citation to a paper by Guo in the specification is not enabling for the whole device and raises the question of the effect of the substrate of the claimed operation.

The details of how the wires are formed, how the coating is performed, and how the wires are brought and held in proximity is discussed in greater detail in the related U.S. Patent 6,459,095 (serial number 09/282,048, not 09/280,048, as previously referenced); see, e.g., Col. 6, line 1 to Col. 12, line 40.

Pages 1 and 7 of the specification have been amended to provide the correct serial number and/or patent number.

Further details of crossed wire arrays are to be found both in instant FIG. 7 and the discussion associated therewith and in related U.S. Patent 6,314,019. Figure 3 of that patent is identical to FIG. 7 of the instant application. Further, Figure 4 of that patent depicts a scalable, defect-tolerant, fat-tree networking scheme; the discussion associated with Figure 4 refers to the instant application (Col. 9, lines 5-12).

Disclosure of an example of the formation of nanoscopic wires is given in A.M. Moreles et al, Science, Vol. 279, pp. 208-268 (Jan. 9, 1998) and J.R. Heath et al, Chemical Physics Letters, Vol. 208, pp.263-268 (June 11, 1993), both cited in Applicants' Information Disclosure Statement enclosed herewith, and listed as references 1T and 2R. Disclosure of an example of how wires are coated, or functionalized, is given by T. Vossmeyer et al, Journal of Applied Physics, Vol. 84, pp. 3664-3670 (Oct. 1, 1998) for silicon (semiconductor) and by D.V. Leff et al, The Journal of Physical Chemistry, Vol. 99, pp. 7036-7041 (May 4, 1995) for gold (metal) and listed as references 4S and 4T, respectively, in the Information Disclosure Statement. These latter two references happen to be directed to nano-crystals, not wires, but the teachings are equally applicable to other nano-structures, such as nano-wires. Disclosure of an example of how wires are positioned with one molecule separation is given in the '048 application in the section called "Examples", via a Langmuir-Blodgett technique. That information has been since published by the present inventors and others in C.P. Collier et al, "Electronically Configurable Molecular-Based Logic Gates", Science, Vol. 285, pp. 391-394 (16 July 1999).

(B) The Examiner argues that one of the functional groups mentioned in the specification is ammonia, and questions how this material is placed and maintained in contact with the wires, since it is not a solid.

As explained in Amendment dated May 18, 2004, in the prior application, ammonia forms a chemical bond with the surface of the wires. Functionalizing the wires includes chemically bonding. The bond may not be strong, that is, it may not necessarily be a covalent bond and may be on the order of van der Waal's forces, but the ammonia serves to functionalize the surface of the wire. Applicants note that the Examiner continues to repeat his objection in the final rejection, but does not respond to Applicants' argument on this point.

(C) The Examiner questions how close the wires must be and what the tolerance is, and further asks if the wires have to be within a separation that is on the order of a molecular diameter. The Examiner also questions how this would be accomplished.

In a preferred implementation, the wires would be about one molecular length apart. For example, the Science paper of July 1999, referenced above, discusses the formation of "a single monolayer of one of three different molecules ... as a Langmuir-Blodgett (LB) film over the entire substrate" (page 392, first column, second full paragraph; see also Fig. 1B).

(D) The Examiner asks what are the design principles that would apply to creating a real device.

The Examiner is not examining the application based on the claim language. In any event, the Examiner is referred to the related U.S. Patent 6,459,095, which includes considerable more detail about the chemistry involved in forming the wires and the junctions. The present application builds on that knowledge to construct a molecule wire transistor. See also, *inter alia*, the instant specification, pages 10-12 regarding the fabrication of a bipolar transistor and pages 13-14 regarding the fabrication of a field effect transistor. Specific discussion is presented concerning pKa, concentrations of molecules, functionalizing, avoidance of tunneling, and controlling distance by the length of the molecules. Molecules will interact and form bonds of various strengths with both wires, and these bonds are self-adjusting to the length of the molecule. Lengths are determined by sizes and configuration of molecule.

(E) The Examiner asks if the functional groups react with the semiconductor or metal quantum wires and if so, what happens to the integrity of the quantum wire structure.

As above, the Examiner is not examining the application based on the claim language. In any event, Applicants are not necessarily using quantum wires; rather, Applicants' wires are characterized as wires of nano-scopic dimensions (a quantum wire is a one-dimensional conductor; electron conductivity is confined to one dimension). Applicants' molecules form bonds with

the wires, and these bonds are known not to damage the wires; the Examiner's attention is also directed to Refs. 4S and 4T, cited above.

(F) The Examiner finally states that no example of a real structure with real materials is given and that it is up to the reader to invent a representative structure, which, the Examiner contends, would involve considerable design and experimental effort, and as such the disclosure is not enabling.

As above, the Examiner is not examining the application based on the claim language. In any event, the Examiner's attention is directed to the instant specification on pages 10-12 (bipolar) and pages 13-14 (FET). Applicants list specific examples of wire materials, e.g., semiconductor (page 11, lines 13-17) and metal (page 13, lines 11-13) and examples of functionalizing molecules (page 11, lines 20-24). Applicants submit that the foregoing description, in conjunction with the teachings in U.S. Patent 6,459,095, would readily guide one skilled in the art.

In summary, the Examiner is not limiting his examination to Applicants' claim language, but is going far afield to insert his own language into the interpretation of the claims. Further, the Examiner is reminded that the level of teaching required is that to enable the person skilled in the relevant art to make and use the invention; the test is not whether the Examiner can make and use the invention. It is well-known that the major advances in the field of nanotechnology are coming from university professors and researchers at major corporate laboratories. The typical researcher in this field has a Ph.D. degree and several years of experience. It is not expected that persons outside of this field or who have a peripheral knowledge of this field, but who are not "persons skilled in the art" would be able to "make and use the invention". Applicants are confident that the requisite person skilled in this art would be able to make and use their invention, based on the teachings herein and on the relevant references cited.

It is true, as the Examiner asserts, that the claims must find support in the specification. Applicants contend that the claims do, indeed, find the requisite support in the specification, both as to the language itself and the referenced U.S. Patent 6,459,095. Applicants also contend, however, that it is the claim language that must find support in the specification, not the Examiner's own language based on his intellectual curiosity.

Reconsideration of the rejection of Claims 16-30 under 35 USC 112, first paragraph, is respectfully requested.

Claims 20 and 24 are rejected under 35 USC 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which Applicants regard as the invention.

With regard to Claim 20, the Examiner questions where the base region is induced in one wire, and contends that if one wire induces a npn in the other that the reciprocal effect is a pnp which form the possible connection.

With regard to the inducing of the base region, the Examiner is respectfully referred to page 11, line 27 to page 12, line 16, wherein it is stated that

> "[t]he two ends of one wire 14 form the emitter 34a and collector 34b. Both ends of the other wire 12, being of opposite conductivity, define a very localized region 36 in first wire 14. The localized region 36 is defined by the diameter of the wire 12 that induces the base of the transistor 32 and thereby defines the emitter 34a and collector 34b. On the other wire 14, which becomes the actual transistor, the length of the base 36 is determined by the diameter of the gate wire 12 and the concentration and pKa of the doping molecules attached to the surface of that wire compared to those on the transistor wire 14." (page 12, line 28 to page 12, line 5.)

With regard to the npn/pnp reciprocal effect, the Examiner is respectfully referred to page 10, line 27 to page 11, line 10, wherein it is stated :

> "Thus, control is achieved as to which doping type will dominate the other when the wires cross." (page 11, lines 9-10.)

From this, it is clear that one configuration, e.g., pnp, is formed on one wire, but the opposite configuration, e.g., npn, is ***not*** formed on the other wire, because the doping type will ***dominate*** and there will be only a minimal reciprocal effect (well below a threshold where it would be of any significance to enabling the construction of the device). The Examiner is assuming a fact ("that the reciprocal effect is a pnp which forms the possible connection") that is simply not true, nor has the Examiner provided any basis for asserting his assumption. Indeed, Applicants respectfully request that the Examiner either provide an affidavit under 37 CFR 1.104(d)(2) in support of his assumption or withdraw the rejection.

Note also page 12, lines 17-19 regarding the creation of the base 36 in the wire 14 by the relative imbalance of doping between the two wires 12, 14. This depends on the relative strength (relative concentration) of the particular Lewis acid and Lewis base combination employed.

With regard to Claim 24, the Examiner states that reference is made to a first portion that is electrically insulating which extends from the metal wire; the Examiner admits to failing to understand this, and questions how the electrical insulation is formed and how it extends from the wire. The Examiner further fails to understand "a second portion" and questions where it is. The Examiner questions the language regarding the inducement of a gate region, and questions whether that means that a channel region is induced, and requires correction

The Examiner's attention is directed to FIG. 6, which illustrates the device that is formed by the method of Claim 24; see also the specification on page 13, lines 24ff. The electrically insulating molecular portion 20a extends from the metal wire 12. Such an insulating molecular portion may comprise the insulating portion of a molecule, for example. It is well-known that a large molecule can have regions of distinctly different electrical conductivities. The second portion 20 is a Lewis acid or a Lewis base. One approach may be to take a Lewis acid or base and provide it with an insulating molecular portion. Reference is also made to Refs. 4S and 4T cited above; techniques are known to bind a specific desired end of a molecule to the wire.

In FIG. 6, metal wire 20 has protrusions 20, 20a extending outward. Each protrusion can be a molecule, with one portion (20a, the thicker portion) comprising an insulator and the portion further out (20, the thinner portion) comprising a conductor. Linear molecules that have an insulating moiety and a conducting moiety are well-known.

Reconsideration of the rejection of Claims 20 and 24 under 35 USC 112, second paragraph, is respectfully requested.

Claims 16-30 are rejected under 35 USC 102(b) as being anticipated by Meyer et al.

Meyer et al disclose a method of forming a nanometer scale interband lateral resonant tunneling transistor with single narrow gate electrode. The transistor is of a single gate design and operation is based on resonant tunneling processes in narrow-gap nano-structures which are highly responsive to quantum phenomena.

Applicants' Claim 16 recites a method for fabricating a molecular wire transistor comprising a pair of crossed wires, at least one of the wires comprising a doped semiconductor ma-

terial. The method comprises providing a first wire having a first conductivity type, providing a second wire with either Lewis acid functional groups or Lewis base functional groups to provide the second wire with a second conductivity type opposite to that of the first wire, and causing the pair of wires to cross, thereby forming a junction with modulation doping where one wire crosses another.

Claims 17-30 depend directly or indirectly from Claim 16.

The Examiner argues Meyer et al show (cover Figure, Figure 3a, Figure 4, and Col. 3, lines 50 et seq.) a quantum effect device with crossed quantum wires where one wire is a semiconductor and the other wire may be regarded as the metal gate 32 or a combination of the metal gate and part of the semiconductor layers. The Examiner further argues that since the semiconductor layers transfer charge due to the band offset effects, they perform modulation doping and are effectively the functional group.

First, Meyer et al disclose that the operation of their device is based on resonant tunneling. Applicants' device is equivalent to a field effect transistor (see, e.g., pages 13-14 of the specification) or a bipolar transistor (see, e.g., pages 10-12 of the specification), neither of which is based on resonant tunneling. Indeed, tunneling would prevent Applicants' device from acting as a transistor; see, e.g., page 10, lines 9-11. Further, Applicants' claimed process would not produce a tunneling diode.

Second, any rejection under 35 USC 102(b) requires that the reference disclose each and every element of the claims. Applicants specifically recite in Claim 16 providing the second wire with either Lewis acid function groups or Lewis base functional groups. Such functional groups are well-known and are disclosed, e.g., on page 11, lines 18-26, which disclose Lewis acids, or electronic withdrawing groups, such as ammonia, hydrogen sulfide, amines, and sulfides, and Lewis bases, or electron donating groups, such as boron-containing compounds (e.g., BF_3.

Meyer et al utterly fail to disclose or even remotely suggest Lewis acid/Lewis base functional groups to achieve modulation doping. The only reference to modulation doping in Meyer et al is found in Col. 6, lines 1-12. There, the modulation doping region 63 is described as "containing indium or gallium dopants". Nowhere in Meyer et al is a method described for forming Applicants' molecular wire transistor in which the method includes providing the second wire with either Lewis acid or Lewis base functional groups. Further, there is not even the slightest

suggestion of providing the second wire with such functional groups. Thus, the Meyer et al reference does not even render Applicants' claims obvious.

The Examiner states that respect to Claim 28, the limitation is a functional limitation which does not carry weight in a claim drawn to a structure.

Claim 28 depends from Claim 16, which is a method claim. Claim 28 recites a preferred limitation of the Lewis acid and Lewis base functional groups recited in Claim 16. Applicants see no basis for the Examiner's comments.

In his comments in his final rejection of the parent application, it appears that the Examiner agreed with the fact that Meyer et al disclose a resonant tunneling device, but argued that it is a transistor nevertheless and shows the claimed device.

Applicants are not claiming a device; they are claiming a ***method*** for making a device. That device is a molecular wire transistor, and is distinctly different than a resonant tunneling transistor, in both its construction and its operation. Applicants' method and the method of Meyer et al are completely different for the construction of the respective devices.

Meyer et al utterly fail to disclose or even remotely suggest Applicants' claimed method, which specifically recites providing a second wire with either Lewis acid functional groups or Lewis base functional groups. Meyer et al is totally devoid of even any remote suggestion of such functional groups, and since anticipation requires a teaching of each and every element of the rejected claim, Meyer et al fails to anticipate Applicants' claimed method. Electrons and holes, which are current carriers, hardly disclose or suggest Lewis acids or bases to provide modulation doping. It is known in the art to use modulation doping to form transistors. However, it is ***not*** known in the art to use Lewis acids or bases for modulation doping. In the event that the Examiner is not familiar with modulation doping, the dopant is outside of the conduction channel.

Finally, Applicants wish to clarify for the record a description of Lewis acid/base doping of semiconductors. The concept for doping nanowires by attaching molecules to the outside of the wires is founded on well known chemistry that is taught at the freshman level in all college and university chemistry departments. The basis for this chemistry is the definition of Lewis acids and bases. A Lewis acid is an electron acceptor, whereas a Lewis base is an electron donor. The prototypical reaction between a Lewis acid and base is the reaction between F_3B (boron trifluoride) and NH_3 (ammonia) to form the molecule F_3BNH_3. In this case,

the F_3B, the acid, is electron deficient (is has a completely empty orbital) and the NH_3 is electron rich (it has a lone pair of electrons). Thus, the B-N chemical bond that forms in the F_3BNH_3 receives both bonding electrons from the ammonia. However, the bond that is formed is a good covalent bond, and in fact it is one of the strongest single bonds known to chemistry. Compare the bond enthalpy of B-N (389 kJ mol^{-}) to C-C (350 kJ mol^{-}) or Si-C (435 kJ mol^{-}). Thus, when looking at Lewis acid-base chemistry, one must realize that often the bonds that are formed are strong **covalent** bonds, and that Lewis acid-base reactions involving ammonia often form new compounds where the ammonia becomes a part of the new compound that is extremely stable chemically.

Now, if we look at the surfaces of nanowires of semiconducting materials, such as Si or GaAs or GaN, we find that they are actually covered by oxides. Those oxides are 'native oxides' simply formed by the exposure of the nanowires to the atmosphere or they are intentionally grown on the nanowires to chemically and electrically passivate them. In this case, electrons can be added or withdrawn from the nanowires by carrying out Lewis acid-base chemistry on the surfaces of the nanowires. For example, oxides of Al and Ga are strong Lewis acids. Thus, ammonia or related amines can bind to Al atoms on the surface of Al oxide to form an Al-N bond, which is also extremely strong, and at the same time donate electrons to the nanowire to make it more n-type. Since the chemistry occurs at the surface of the passivating layer on the nanowire, no scattering center is introduced into the nanowire, so the electron mobility is maintained as more carriers are added (thus, the use of the term 'modulation doping' was used in analogy to the types of structures that are grown in the semiconductor industry as layers, such as AlAs/GaAsAlAs, in which the dopants are placed in the high band gap AlAs layers and the carriers move into the GaAs layer). In fact, a more accurate description of this process is surface doping, since the dopant species are not incorporated in the passivating oxide but are chemically bonded to the surface.

Another example is a silicon dioxide (SiO_2) passivating layer on a Si nanowire or on any other nanowire onto which it may be coated. Chemically, silicon dioxide is an acid anhydride (an acid with the water removed). Actually, silicon dioxide is amphoteric, and depending on how the surface is prepared, it can be either acidic or basic. Thus, if the surface is prepared in an acidic or over-oxidized form, it also can react strongly with ammonia or other amines to form strong Si-N bonds (439 kJ mol^{-}) and donate electrons into the passivated

nanowire. On the other hand, silicon dioxide can be reacted with F_3B or other Lewis acid to form Si-B (289 kJ mol^{-}) or O-B bonds and withdraw electrons from the nanowire. Thus, by selection of the appropriate surface oxides and surface reactants, Lewis acid-base chemistry can be used to add (n-type dope) or withdraw (p-type dope) electrons to a nanowire by forming chemical bonds between the electron donor or acceptor and the passivating layer (oxide or other chemically stable and electrically inert coating) of a nanowire. Prior to bonding, Lewis acids and Lewis bases are typically fluids (liquids or gases).

The Examiner argues that "all materials are either a Lewis acid or base". This is utterly without foundation. Certainly, no chemist would consider bulk solid materials (e.g., silicon, germanium, gallium arsenide, and other conventional semiconductors), doped or undoped, to be a Lewis acid or base; these materials are commonly employed in the construction of transistors, such as disclosed by Meyer et al. The Examiner is respectfully required to provide an affidavit under 37 CFR 1.104(d)(2), as to the basis for this statement. Inasmuch as this statement is crucial to his rejection of the claims over Meyer et al, Applicants expect withdrawal of this statement and withdrawal of the rejection based on this statement.

Summarizing, Meyer et al utterly fail to disclose or even remotely suggest modulation doping of their resonant tunneling devices using Lewis acids/bases. Since this element is missing from the reference, there can be no anticipation. Further, since the reference does not even suggest Lewis acids/bases for modulation doping, then Meyer et al fail to render Applicants' claims obvious.

Reconsideration of the rejection of Claims 16-30, as amended, under 35 USC 102(b) as being anticipated by Meyer et al is respectfully requested.

Claims 16-30 are rejected under 35 USC 102(b) as being anticipated by Frazier et al.

Frazier et al disclose a quantum effect switching device comprising a substrate, first and second tunneling barriers, and a quantum well. The current between a drain region and the substrate can be switched by placing a potential on a gate layer. The potential on the gate layer selectively modulates the effective dimensions of the quantum well to alter the allowed energy levels within the conduction band of the quantum well.

Applicants' Claims 16-30 are discussed above.

The Examiner argues that Frazier et al show (cover Figure and Col. 7, lines 20 et seq.) a device consisting of crossed quantum wires where one wire is specifically stated to be a semiconductor and the other wire is specified to be conducting and which could be a semiconductor.

The device of Frazier et al, like that of Meyer et al, is based on tunneling; see, e.g., Col. 3, lines 32-65, which disclose a first tunnel barrier layer 14 and a second tunnel barrier 18. Accordingly, the comments made above regarding Meyer et al obtain here as well.

As with Meyer et al, Frazier et al is totally devoid of any disclosure or even remote suggestion of using Lewis acid/Lewis base functional groups for modulation doping. Thus, Frazier et al fail to anticipate Applicants' claimed invention and even fail to render the claims obvious. The comments made above regarding the Examiner's contention that everything is either a Lewis acid or base obtain here as well.

Reconsideration of the rejection of Claims 16-30 under 35 USC 102(b) as being anticipated by Frazier et al is respectfully requested.

The foregoing amendments and arguments are submitted to place the application in condition for allowance. The Examiner is respectfully requested to take such action. If the Examiner has any questions, he is invited to contact the undersigned at the below-listed telephone number. HOWEVER, ALL WRITTEN COMMUNICATIONS SHOULD CONTINUE TO BE DIRECTED TO: IP ADMINISTRATION, LEGAL DEPARTMENT, M/S 35, HEWLETT-PACKARD COMPANY, P.O. BOX 272400, FORT COLLINS, CO 80527-2400.

Respectfully submitted,

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